Space Weather Technical Forecast

Issued on Tuesday 24 December 2024 at 13:23 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Further R1/R2 radio blackouts expected. G1-G2/Minor-Moderate Geomagnetic Storms likely 25-26 Dec.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate with three M-class flares observed. A peak flare measured at M4.8 was observed from AR3932 at 24/0019 UTC.

There are now thirteen sunspot regions on the visible disc, with the addition of an unnumbered bipolar region in the far northeast. This region may well reveal more complexity as it rotates further into view. The southeast quadrant remains the focus of solar activity, containing a cluster of the three largest regions (AR3928, AR3932 and AR3933). AR3928 and AR3933 have both undergone growth in their main trailing spots. Despite a slight decrease in size, AR3932 has developed a small delta spot in its southern region. Elsewhere, in the northeast, AR3936 saw growth in its main trailing spot. Other remaining regions are more magnetically simple and generally unchanged.

A moderately-fast CME associated with the M8.9 solar flare and sympathetic filament eruption was modelled as an expected, flanking impact on 25 Dec, or perhaps early 26 Dec. Analysis continues into two CMEs associated with recent M-class flares from AR3932.

Solar Wind / Geomagnetic Activity: Solar winds, observed at L1 by DSCOVR and ACE were elevated to strong, varying between around 520-630km/s. Density was likely below average. The Interplanetary Magnetic Field (IMF), Bt, was weak between 4-7nT. The north-south component, Bz, varied weakly throughout, ranging between +6 and -6nT, with no single direction predominant. Phi angle was mainly negative (towards the Sun). Geomagnetic activity was Quiet to Unsettled (Kp1-3).

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) was well below the S1/Minor Storm threshold, but slightly elevated above normal background levels, on a slowly declining trend. High energy electron flux (greater than 2MeV) observed by GOES16 varied between moderate and high levels, with a peak of 1540pfu observed at 23/1725UTC. The associated 24-hour fluence was below the Active (1e8 integrated flux) threshold throughout. The 24/0000UTC observation was 4.32e7 integrated pfu, with a slow, rising trend.

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Four-Day Space Weather Forecast Summary

Solar Activity: Further M-class flares are expected, with a slight chance of isolated X-class flares maintained throughout.

Solar Wind / Geomagnetic Activity: A CME that left the Sun late 20 Dec has a now reducing chance to give Earth a glancing impact early on Day 1 (24 Dec). A moderately-fast CME on 23 Dec from a flare and subsequent filament eruption in the southeast disc is expected to result in a flanking impact on Day 2 (25 Dec), or perhaps arriving early Day 3 (26 Dec). No other potential Earth-directed CMEs feature in the forecast, however, due to the sheer number of CMEs in evidence in solar imagery over the past several days, confidence in this aspect of the forecast is lower than usual.

The ongoing coronal hole solar wind enhancement, giving elevated wind speeds, is expected to continue until Day 2 (25 Dec) before slowly declining. Further connection to a coronal hole in the northwest disc is possible from Day 3 (26 Dec) onwards, but considered unlikely given its high-latitude location.

Geomagnetic activity is expected to be mainly Quite to Unsettled on Day 1 (24 Dec) with a chance of Active intervals. On Day 2 and 3 (25 and 26 Dec), dependent on any CME arrival, peak G1-G2/Minor-Moderate Storm levels are likely. By Day 4 (27 Dec), mainly Quiet to Unsettled activity is forecast, but with a chance of Active periods, especially at first.

Energetic Particles / Solar Radiation: There is a slight chance of S1-level or greater enhancements during the period. In the absence of any further notable flares, ongoing slightly enhanced high-energy Proton counts should ease towards normal background levels in the coming days.

The high energy electron forecast carries lower-than-average confidence due to inherited uncertainties from the geomagnetic forecast, especially surrounding any potential glancing CME influence between Days 1-3 (24-26 Dec). Overall, the chance of exceeding the Active (1e8 integrated) threshold is greater than usual, with the main risk of exceeding occurring Day 2 (25 Dec).

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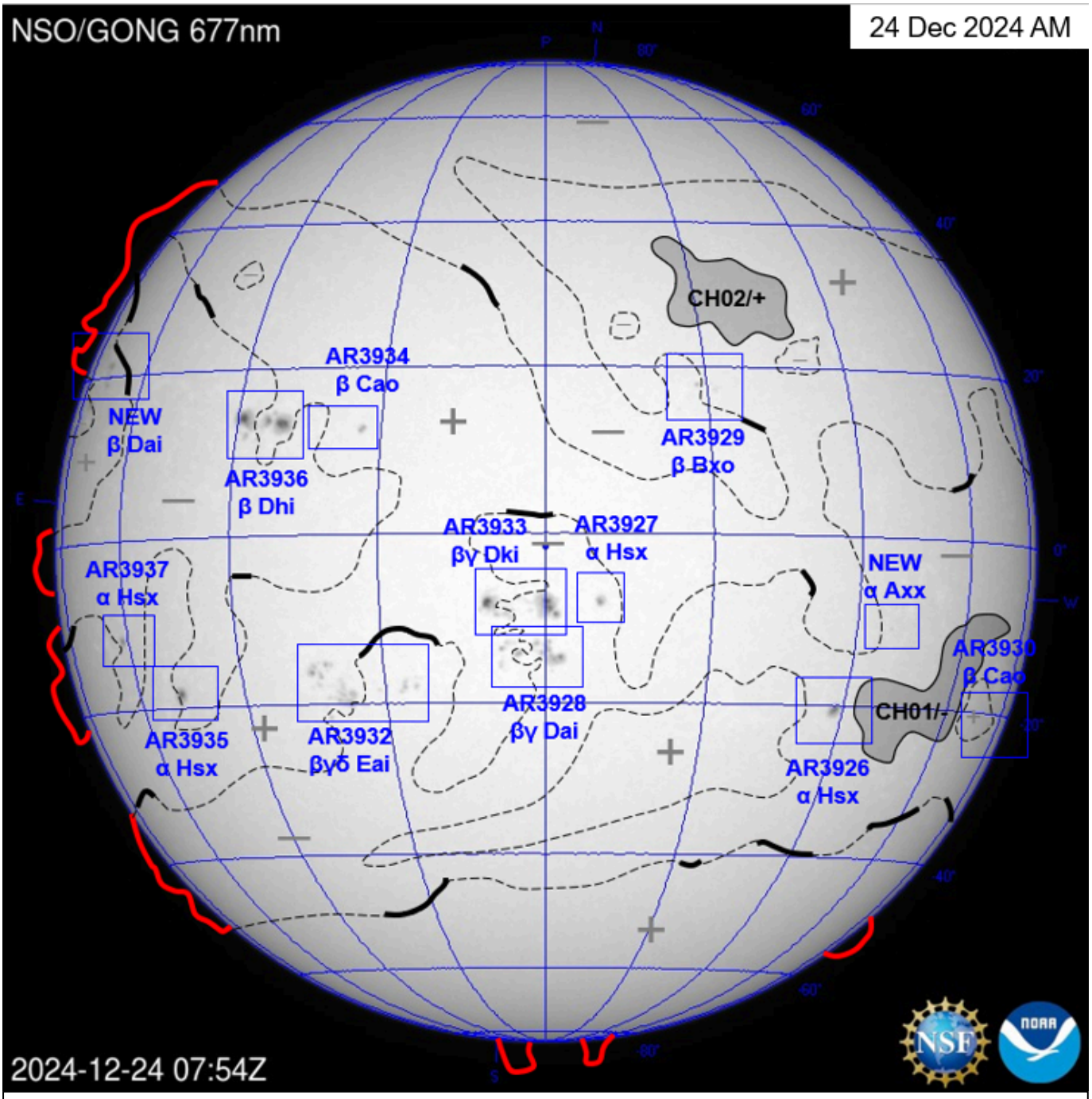
Figure 1: Solar Synoptic Map Valid 24/0800UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms

A filament lift-off from the northeast disc late 20 Dec was modelled and gives a possible peripheral glance early on Day 1 (24 Dec) although this now looking increasingly unlikely. On 23 Dec a M8.9 flare from AR3923 and a nearby, sympathetic filament lift-off in the southeast disc resulted in a moderately-fast CME. Although the bulk of the ejecta is modelled to pass below the Earth-Sun line, a flanking impact is considered likely on Day 2 (25 Dec), with a chance of a delayed arrival early Day 3 (26 Dec). No other potential Earth-directed CMEs currently feature in the forecast, however, due to the sheer number of CMEs in evidence in solar imagery over the past several days, confidence in this aspect of the forecast is lower than usual.

Solar winds are Elevated due to ongoing connection to CH01/-. Influence from this feature is expected to persist through Days 1-2 (24-25 Dec), before declining, though this decline may be masked by anticipated CME influence, indicated above. A further enhancement is possible, but unlikely on Days 3 and 4 (26 and 27 Dec) from CH02/+ located in the northwest disc. This feature is non-recurrent and also may be located at too high a latitude on the disc to connect with Earth, reducing confidence in any impacts, though these would likely be minor should any enhancement occur.

Geomagnetic activity is expected to be mainly Quiet to Unsettled on Day 1 (24 Dec) with a chance of Active intervals. On Day 2 and 3 (25 and 26 Dec), dependent on any CME arrival, peak G1-G2/Minor-Moderate Storm levels are likely, with a slight chance of G3/Strong Storm intervals should we happen to see a stronger connection. By Day 4 (27 Dec), mainly Quiet to Unsettled activity is forecast, but with a chance of Active periods, especially at first.

Geomagnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	10	70	70	10
Strong	G3	No	1	10	10	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

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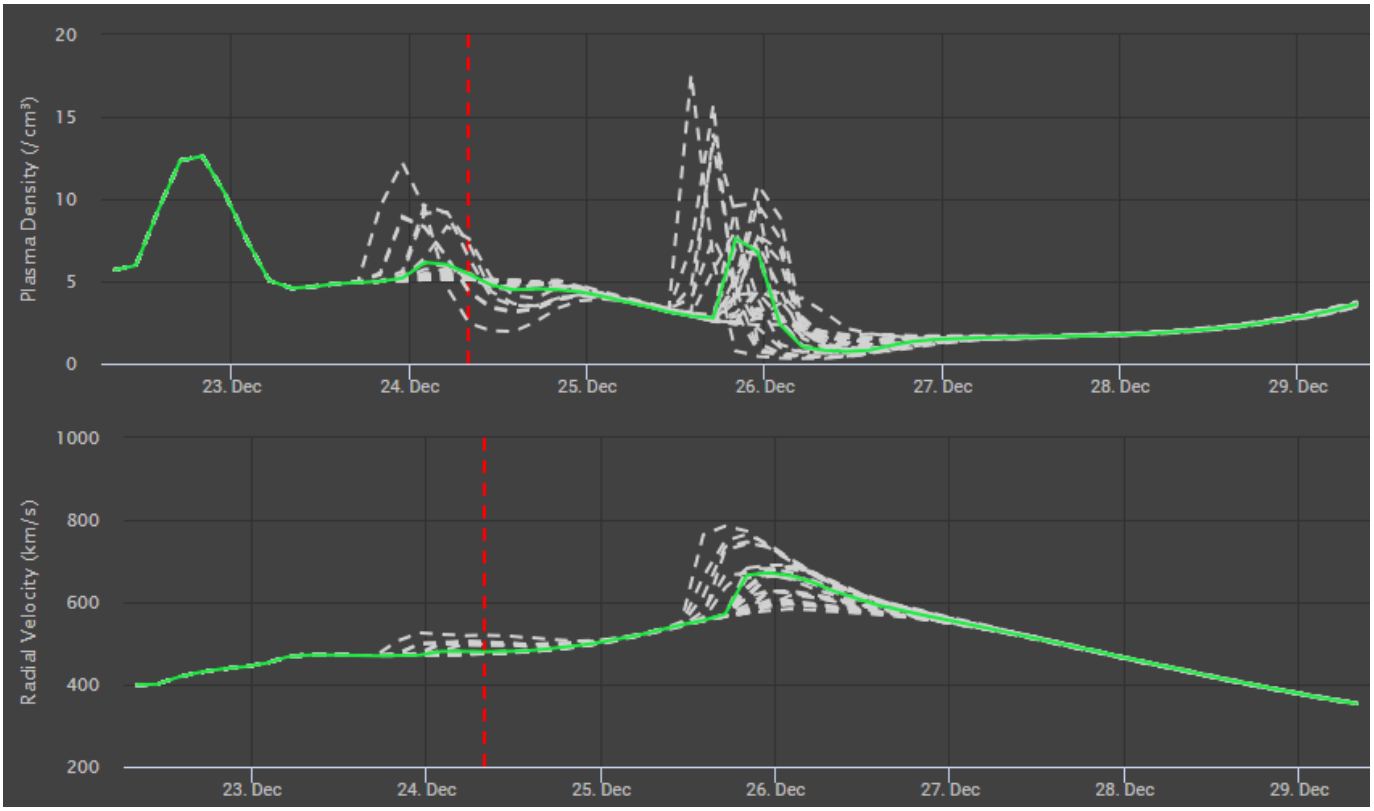
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
21/0535 UTC	Partial	Filament	NE quadrant	532	24/0000 UTC	Possible glance. Low confidence.
23/1550 UTC	Partial	Flare and Filament	SE disc (AR3932)	780	25/1800 UTC	Likely flanking impact. Moderate confidence on timings. +/- 9 hours from Estimated Arrival Time.

Figure 2: Latest MOSWOC ENLIL Ensemble output. Note forecast for a more significant connection and stronger enhancement to the solar winds following the second CME glance, thought associated with CH02/+ from 25 Dec onwards, is considered likely to be erroneous given the regions' high-latitude location on the disc.



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Radio Blackouts - X-Ray Flares

Solar activity is at Moderate levels with observed background flux continuing to rise. A peak flare measured at M4,8 was observed from AR3932 at 24/0019 UTC. There are currently thirteen sunspot regions on the visible disc, including two unnumbered groups. The southeast quadrant remains the focus of solar activity, containing a cluster of the three largest regions (AR3928, AR3932 and AR3933). These are moderately large bipolar spot groups and show some degree of magnetic complexity and areal growth. AR3932 may also contain a small delta spot in its southern region, although a lack of high-resolution imagery makes confirmation of this challenging at this time. This region supply the bulk of current flare activity, with occasional impulsive flares seemingly a feature of its current configuration. Other remaining sunspot groups on the disc are relatively small, stable and more magnetically simple.

A new region containing numerous spots is rotating over the northeast horizon, with significant magnetic looping present in SUVI imagery. This may present a risk of notable flares in the forecast period. Another region, likely returning Ex-AR3912, may also rotate onto the visible disc from Day 1 (24 Dec). This region previously responsible for X-class flare activity earlier in December and was perhaps the source of a large far-sided CME on 17 Dec. If the sunspot has maintained its complexity it could contribute to higher flare probabilities in the upcoming days although far-side sounding imagery does suggest this region may have faded somewhat.

The assessment of any new regions notwithstanding, flare risk looks to remain elevated during the period and further M-class flares are expected, with a slight chance of X-class flares maintained throughout.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	80	80	80	80
Very Active	R3-R5 (X Class)	No	10	10	10	10

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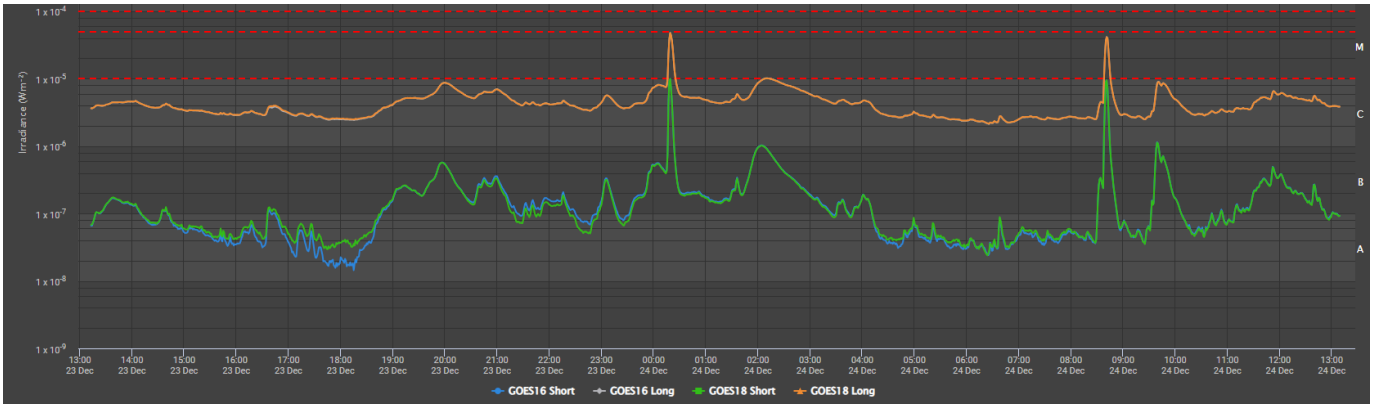
Figure 3: Latest 24hr GOES16/18 X-Ray Flux trace.



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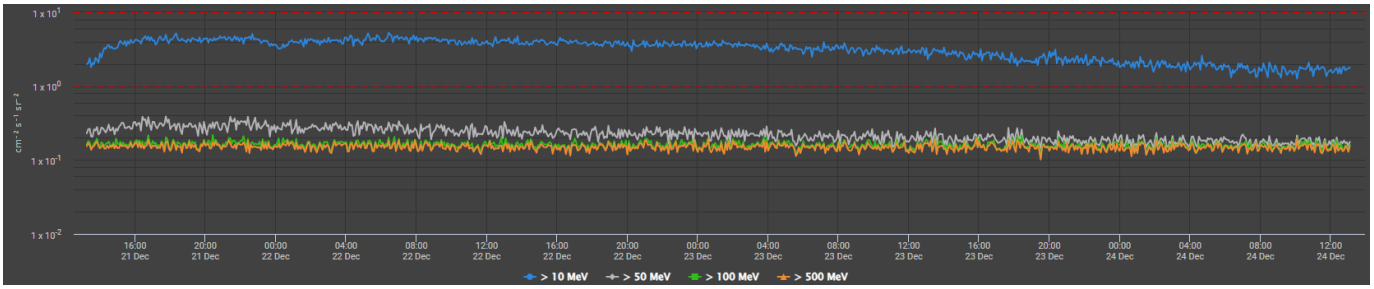
Solar Radiation Storms (High Energy Protons)

The source of the currently observed slight enhancement in the near-Earth environment is somewhat uncertain, but a far-sided source on 19 Dec seems most likely. High-energy Proton counts are now slowly declining towards background levels. There is a daily slight chance of S1/Minor Proton storms or greater, should any further significant flares occur, increasing to a chance on Day 4 (27 Dec) as the larger, more complex regions on the facing-disc advance into more favourable western locations for connection with Earth. In the absence of any notable flares, slightly raised proton counts should ease towards typical background values in the coming days.

Radiation Storms Probability (Exceedance)	Level ($cm^{-2}sr^{-1}s^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	20	20	20
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Latest 72hr GOES18 Proton Flux trace.



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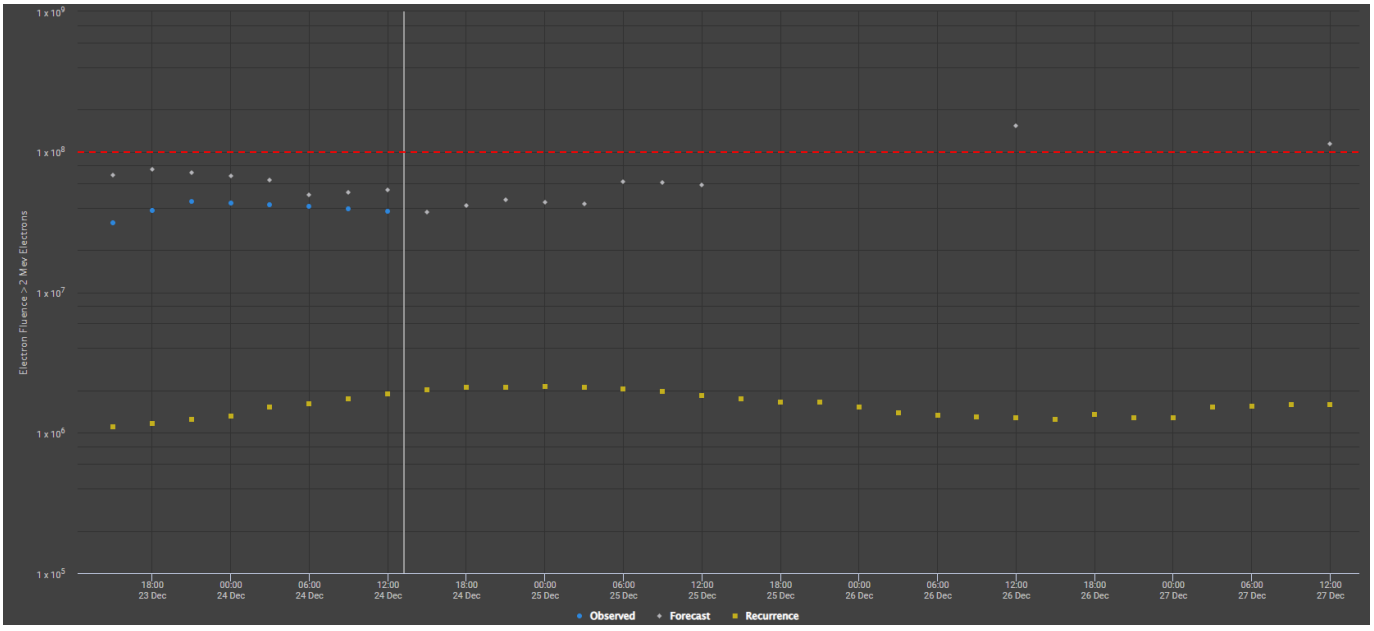
High Energy Electrons (≥ 2MeV)

Current high energy electron flux is oscillating between moderate and diurnally high levels. This trend is likely to continue at GEO to start the period, as solar wind pressure from CH01/- slowly starts to ease, with more extended periods of high flux considered likely in the absence of any potential CME arrival on Day 1 (24 Dec). The expected arrival of a CME on Day 2 (25 Dec), or perhaps early Day 3 (26 Dec), is more likely to temporarily suppress electron counts, before potentially increasing again by late Day 4 (27 Dec). There is a small likelihood that the onset from the fast-wind of CH02/+ could occur from Day 3 (26 Dec) onwards to further suppress electron flux, but this is considered unlikely to connect strongly with Earth.

Electron fluence is forecast to remain below the Active threshold for much of the period, but with a likely exceedance on Day 2 (25 Dec). Given uncertain CME and fast-wind influence, the forecast carries lower than average confidence levels, and although MOSWOC REFM output appears to give a reasonable steer for the upcoming days it will not factor in potential CME arrival, rendering anything later Day 2 (25 Dec) onwards low confidence.

GEO Electron Environment	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10^{8}	No	10	60	40	30
Very Active	≥ 2 MeV ≥ 1×10^{9}	No	1	1	1	1

Figure 5: Latest MOSWOC REFM output.



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